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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Andrew C. Gallagher

DETECTION OF HANGING WIRES IN DIGITAL COLOR IMAGES

Serial No. 10/816,317

Filed 01 April 2004

Group Art Unit: 2609

Examiner: Thomas M. Redding

Commissioner for Patents
P.O. Box 1450
Alexandria, VA. 22313-1450

Sir:

Interview Agenda

As the Examiner has requested the following is a brief interview agenda for the telephone conference call scheduled for November 14, 2007 at 9:00 am. This agenda should take no more than ½ hour.

A. Brief review of claim 1 and problem of the word "automatic." Filed herewith is a Power Point presentation. This will briefly be discussed, particularly with reference to page 16. (10 minutes)

B. Andrew Gallagher will briefly discuss the prior art and the problems associated with hanging wires. He will point out that the cited prior art only corrects defects except for one reference which takes an aerial view to show wires that are down. (10 minutes)

C. Respond to any questions raised by the Examiners. (10 minutes)

The issues involved in this case can be easily presented. If the Examiner has any problems with this agenda, Applicant's attorney would appreciate a telephone call.

Respectfully submitted,

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Improved Blue Sky Detection Using Polynomial Model Fit

Andrew C. Gallagher, Jiebo Luo, Wei Hao

Presented By: Majid Rabbani

Eastman Kodak Company

Motivation

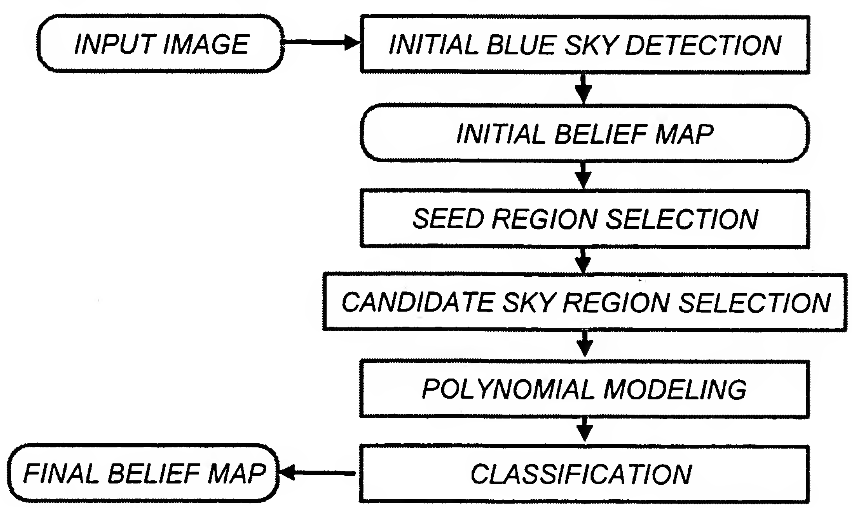
- Problem statement
  - About 1/2 of consumer photos are taken outdoor
  - About 1/3 of the photos contain significant pieces of sky
  - Detection of key subject matters in photographic images to facilitate a wide variety of image understanding, enhancement, and manipulation
- Applications
  - Scene balance
  - Image orientation
  - Image categorization (indoor/outdoor)
  - Image retrieval
  - Image enhancement

Prior Art on Sky Detection

- Many methods focus on color
  - Color classification, Saber et al., 1996
  - Color + location (orientation) + size, Smith et al., 1998
  - Color + texture + location (orientation), Vailaya et al., 2001
- Drawback with the prior art
  - Unable to reject other similarly colored/textured/located objects
  - Some need to know image orientation
- Moving beyond color
  - A ***physical model*** is desirable to characterize the physical appearance of blue sky (Luo et al, ICPR 2002)
  - Low false positive rate, but small sky regions are missed because they are too small to exhibit proper gradient signal
  - An extension to the model is needed to reduce the false negatives (missing small regions)

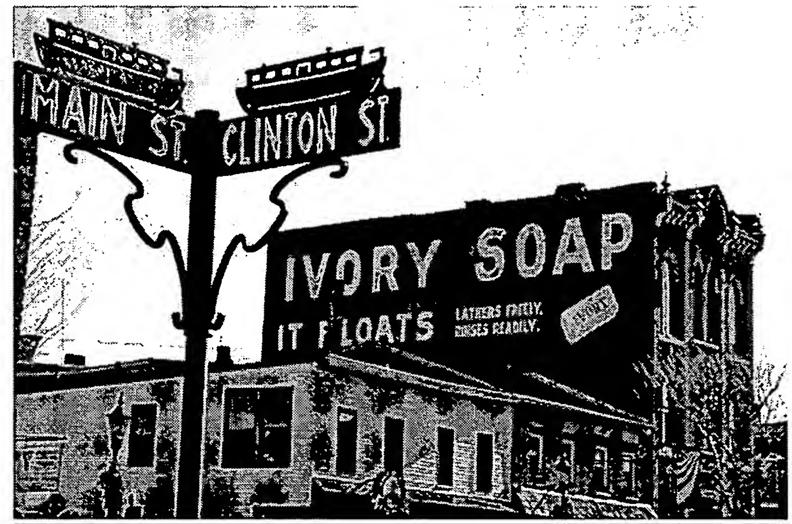
Overview of the Sky Detection Method

- An initial sky belief map is generated using Luo et al., 2002.
- A seed region is selected from the non-zero belief regions
- Candidate sky regions are selected
- Polynomial modeling is used to determine which candidate sky regions are consistent with the seed sky region
- A final belief map of complete sky is produced



Initial Blue Sky Detection

- Physical model-based method by Luo et al., 2002 is used
  - **Stage 1: Color Classification**
    A trained neural network assigns a probability value to each ***pixel***. An image-dependent threshold is determined.
  - **Stage 2: Signature Verification**
    A final probability for each ***region*** is determined based on the fit between the region and the physics-based model.



Original

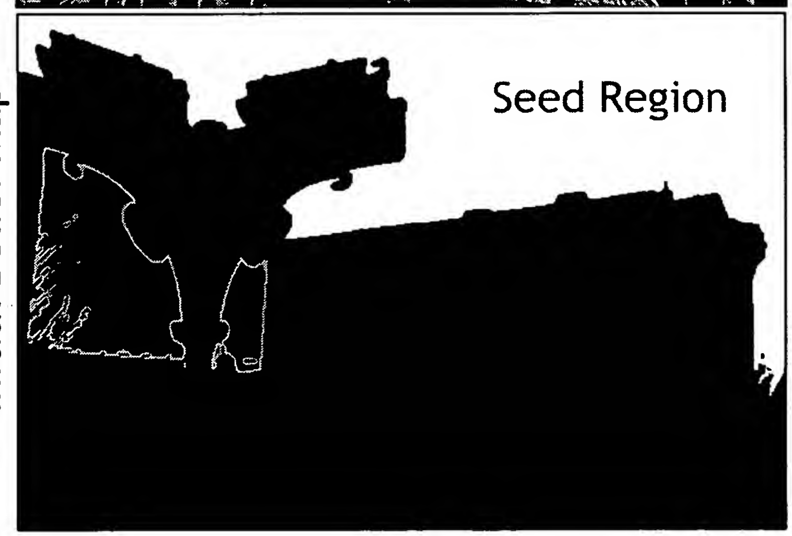
Initial Belief Map

Seed Region Selection

- Each non-zero belief region in the belief map is examined and a score is computed
- The region having the highest score is the seed region
- Having a single seed region prevents conflicts that may lead to false positives.

Original

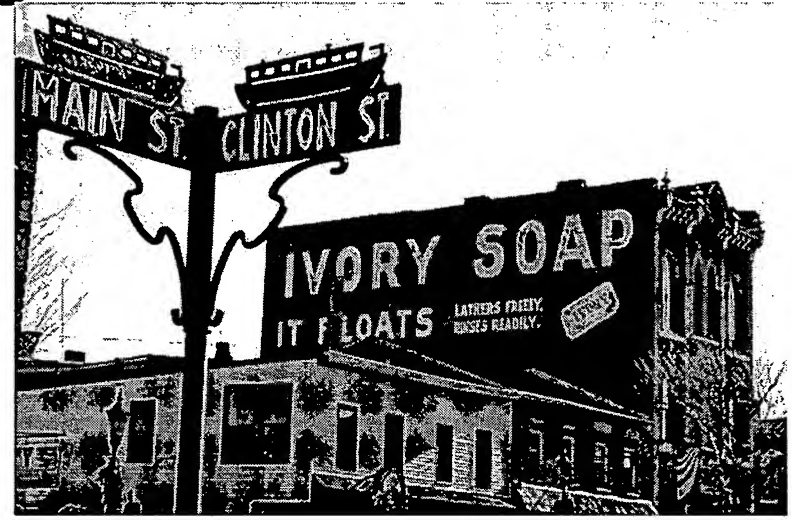
Initial Belief Map



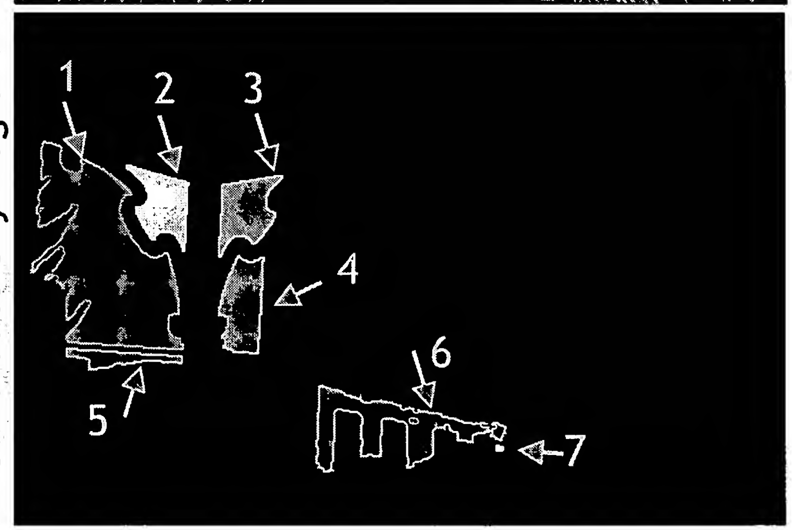
Candidate Sky Region Selection

- Sky colored regions from the initial blue sky detector (including regions initially rejected) are examined to find candidate sky regions
- Candidate sky regions must be free of texture
- The seed region cannot be a candidate sky region

Original



Candidate Sky Regions



Polynomial Modeling- Stage 1

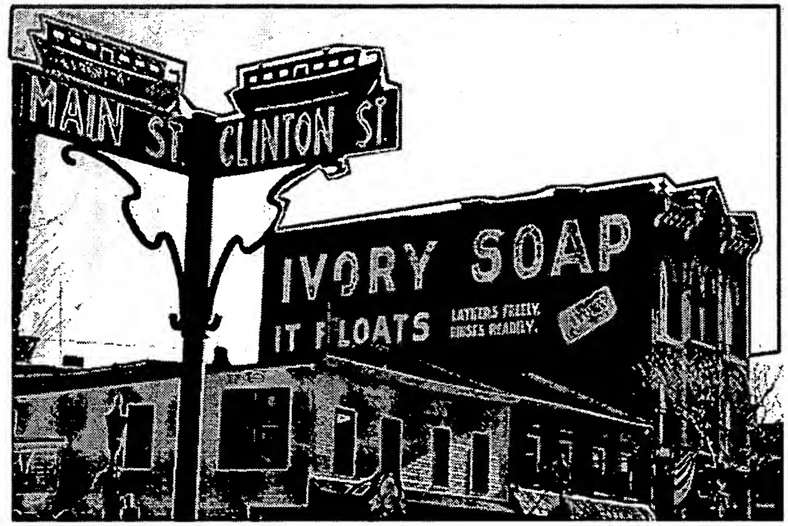
- A two-dimensional model is fit (via least squares) to each color channel of the seed region

$$\begin{bmatrix} \hat{r}(x,y) \\ \hat{g}(x,y) \\ \hat{b}(x,y) \end{bmatrix} = \begin{bmatrix} r_c^T \\ g_c^T \\ b_c^T \end{bmatrix} [x^2 \quad xy \quad y^2 \quad x \quad y \quad 1]$$

$\hat{r}(x,y)$, $\hat{g}(x,y)$ and $\hat{b}(x,y)$ are pixel value estimates.

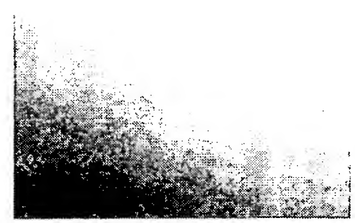
r_c, g_c and b_c are the polynomial coefficients.

- Model errors are computed for each color channel



Original

- Model error for example seed region is: 2.2 1.4 0.9 in red,grn,blu

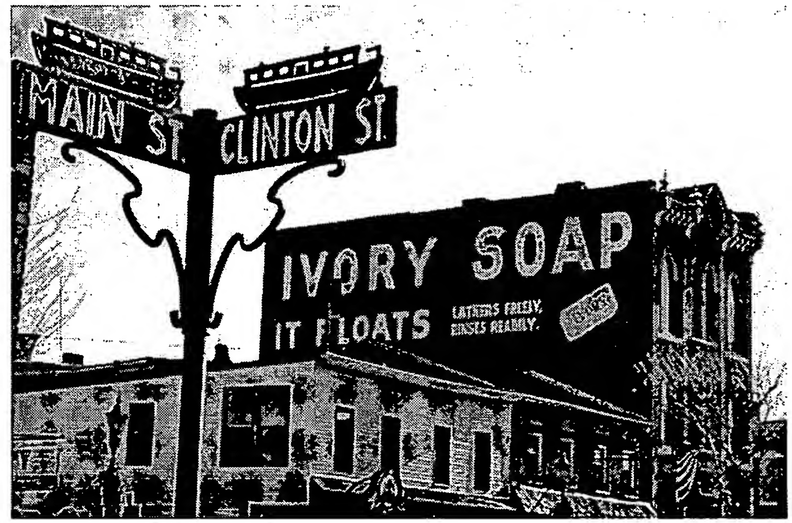


Visualization of the polynomial for the entire image

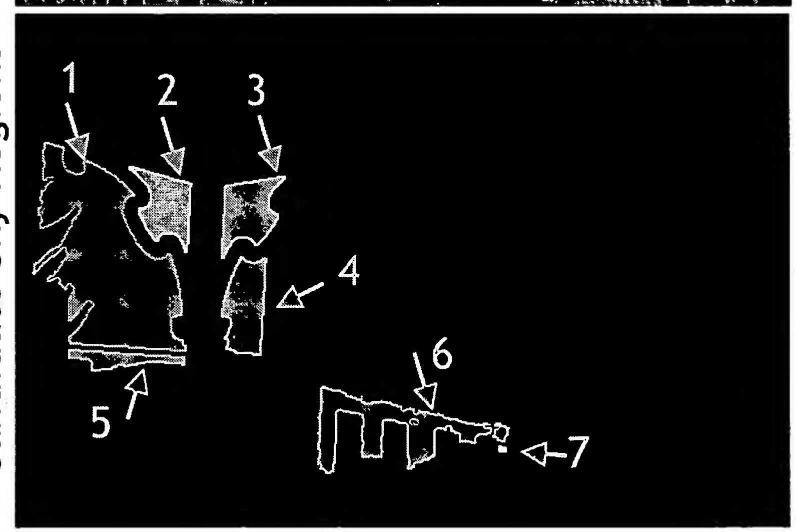
Polynomial Modeling- Stage 2

- A second polynomial is fit to both the seed region and a candidate sky region
- Model errors for stage 2 are computed for each color channel over *just the candidate sky region*
- Assuming both the seed region and the candidate sky region are sky, the model errors should be low (on the same order as the errors from stage 1)

Original



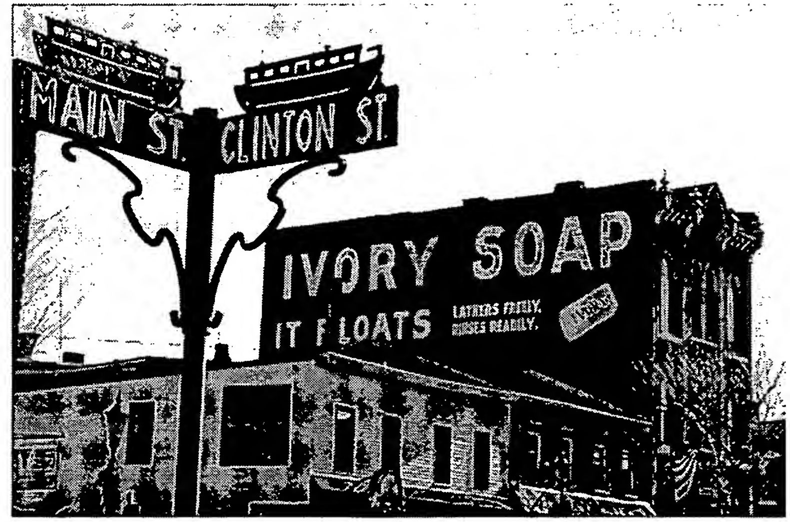
Candidate Sky Regions



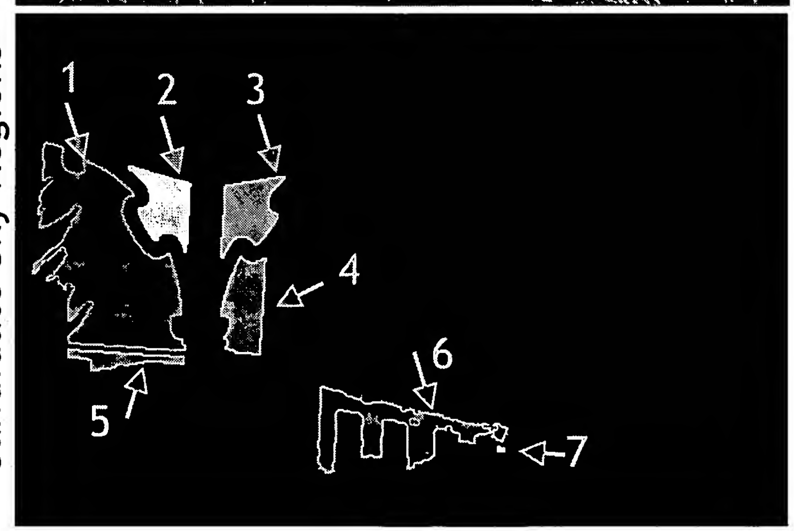
Classification

- A candidate sky region is classified as sky when:
  - The stage 2 errors are less than T_0 (preferably 4.0) times the stage 1 errors
  - The stage 2 errors do not exceed a threshold T_1 (preferably 10.0)
- The assigned belief value is equal to the seed region belief value
  - Regions can be "promoted" in their belief value

Original



Candidate Sky Regions



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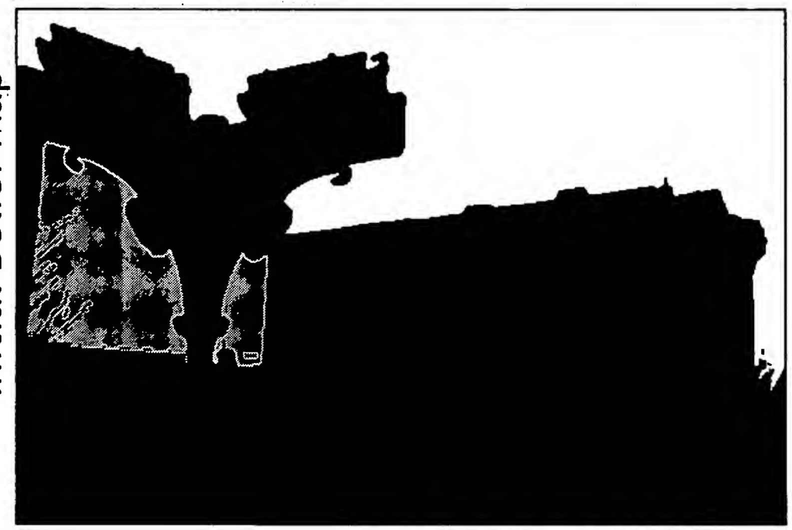
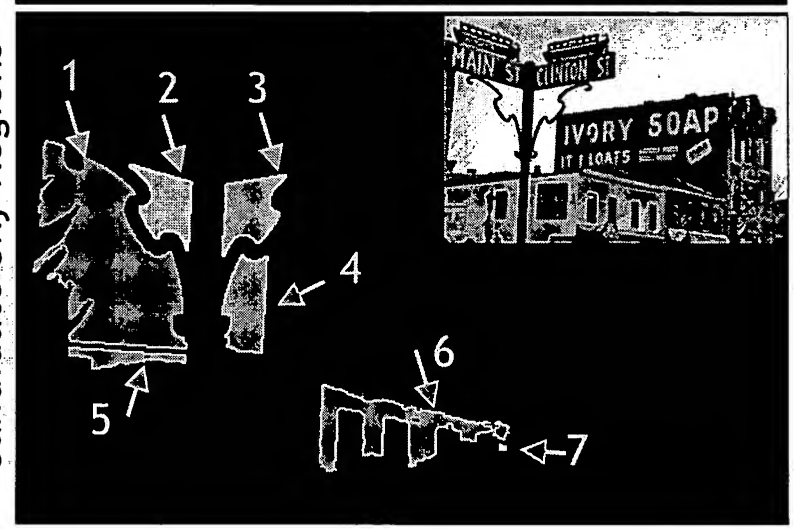
Classification Results

Region	Result	Correct?
1	promoted	yes
2	included	yes
3	included	yes
4	promoted	yes
5	included	yes
6	not included	yes
7	not included	yes

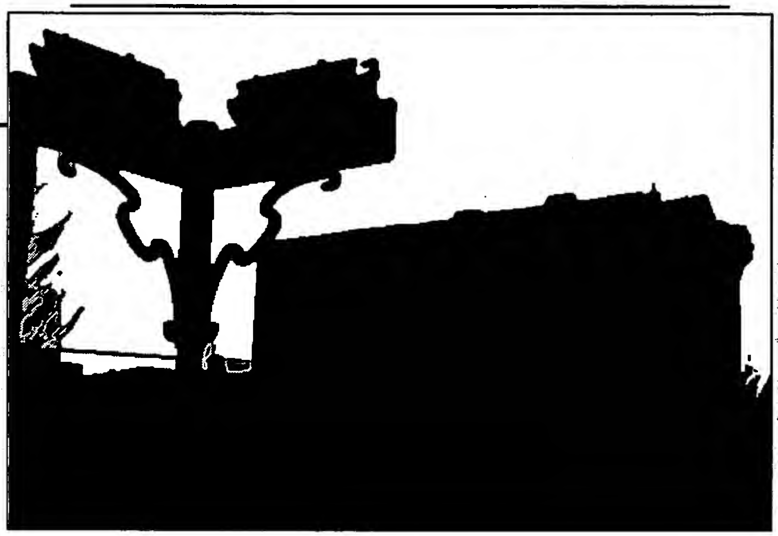
Initial Belief Map



Candidate Sky Regions



Final Belief Map



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Experimental Results

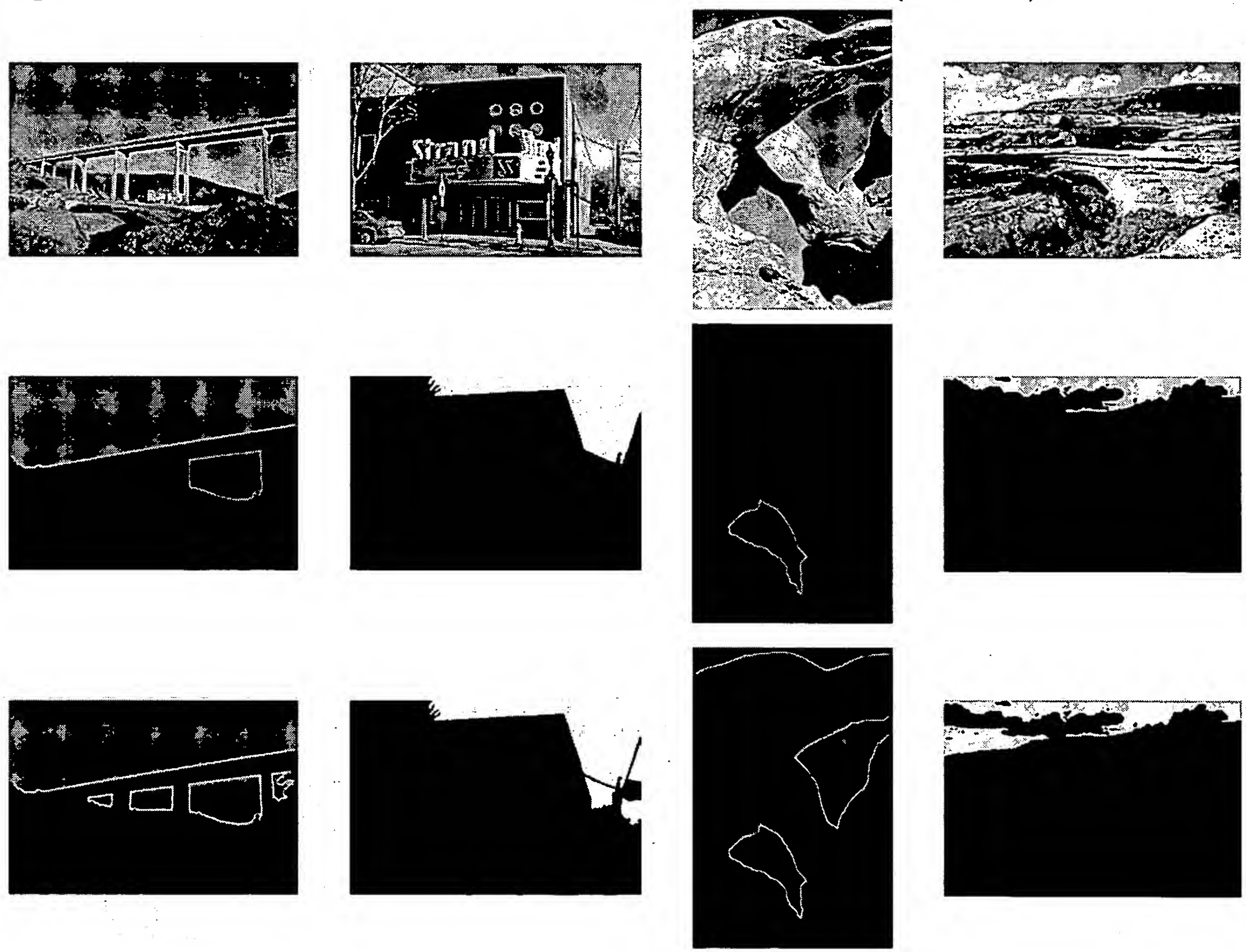
- The algorithm was applied to 83 images with at least one sky region classification from the initial sky detector
- Initial sky detector performance
  - 88 correct detections
  - 16 false positives
  - Precision: 85%
- Polynomial model fitting results
  - 31 ***additional*** correct detections
  - 8 additional false positives
  - 6 correct promotions of a region's belief value
  - Precision: 82%

Experimental Results (TP)

Original

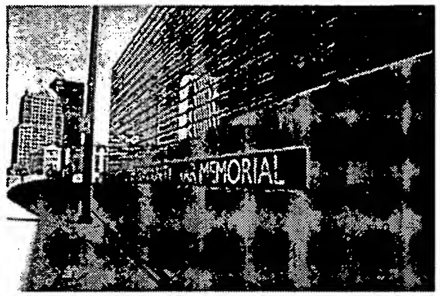
Initial Sky Belief Map

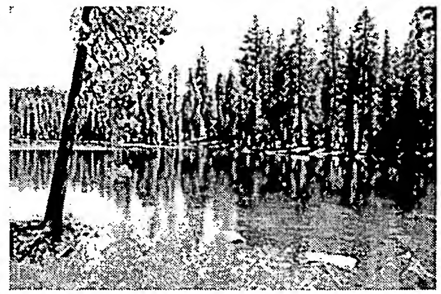
Final Sky Belief Map



Experimental Results (FP)

Original





Initial Sky Belief Map

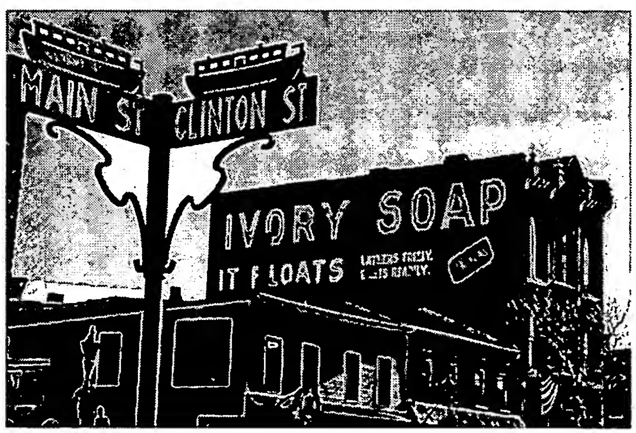
Final Sky Belief Map

- Most (6 out of 8) false positives were reflections of sky
- These regions were small and nearly uniform, else they would have been rejected for exhibiting an opposite gradient to the seed region

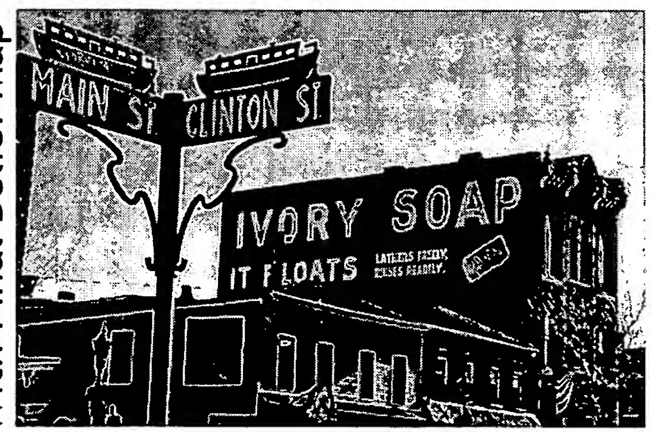
Image Enhancement

- The sky belief map can be used to alter the sky saturation to achieve more pleasing color
- This requires a complete, accurate belief map

Original



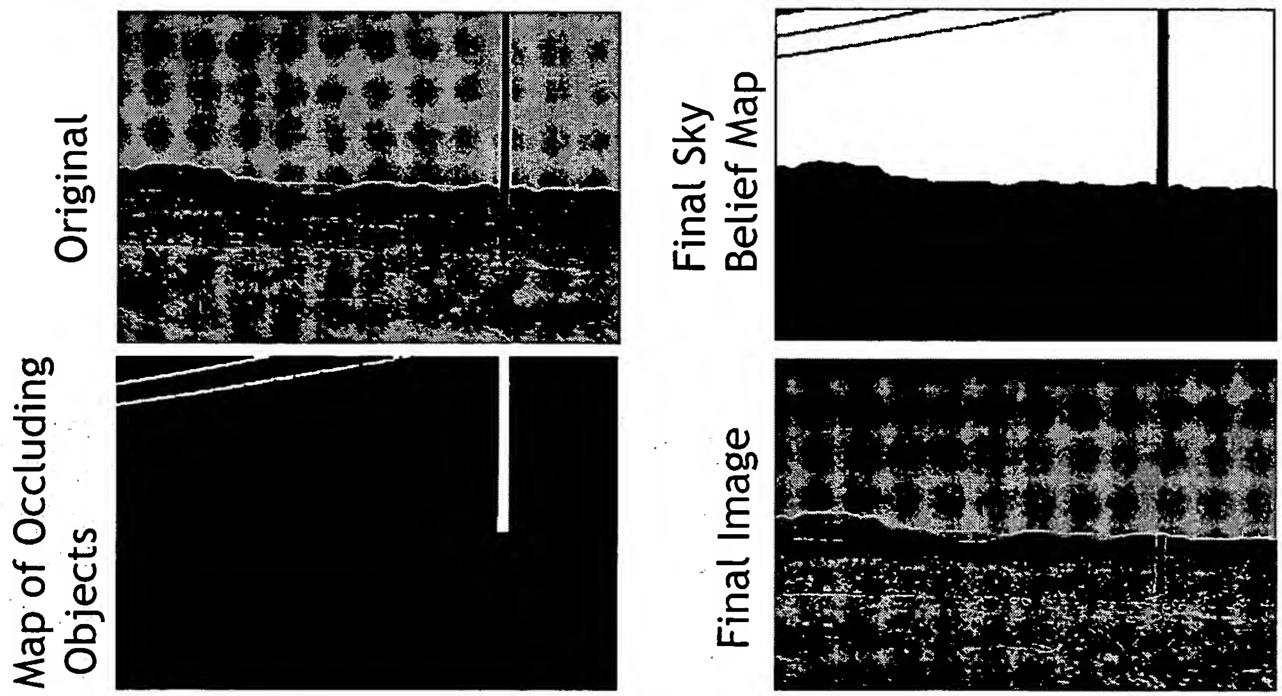
With Initial Belief Map



With Final Belief Map

Image Enhancement

- The polynomial can also be used to hypothesize the image without objects that occlude the sky
- The sky belief map is analyzed to find sky occluding objects, which are "filled in" using the polynomial



Conclusions

- Detection of blue sky is a fundamental content understanding problem relevant to a large number of consumer image related applications

- The polynomial model fitting takes advantage of the spatial smoothness of sky, building a model from known sky regions to augment additional regions into a complete sky belief map